Introductory Lecture ...

for

— 1817 —

By

James Rush

I have come before you Gentlemen to
deliver an introduction to the lectures
of the late Dr. Benjamin Rush, on the in-
stitutes and practice of Medicine, which
I shall read during the ensuing winter.
It is common on occasions like the present
to give a history of the origin and progress
of the branches of Medical science to be
taught: and to announce the plan of
instruction contemplated in them. -
The lectures I shall read have a value
that will be best received by the entire
study of them, and they have long possessed
a character that renders any allurement offered
by the promulgation of their plan, altogether
unnecessary. - Nor will I occupy your
time with the history of Medicine. Such
a history can propose nothing new, and
offer no instruction that has not long

Additions to various
parts of this lecture ——

Much has been said by pathological
authors of venous and arterial
congestions or plethoras, the views I have
given, will shew that a venous plethora
cannot take place from mere rapidity
of circulation, and can only arise from
obstruction of the veins, or from the contraction
of the universal areas of the arteries — Whe-
ther the an arterial plethoras can take
place from the exertion of the tonicity
of the veins, may require further observa-
tion —

A weak or strong action of the heart
or an obstruction of the large trunks of veins
or arteries, cannot alter the flux of blood
thro the circuit — for since that obstruction
is in the course of the circle, the obstacle

ago become familiar to the youngest student
nor would I willingly be guilty of ~~[illegible]~~
~~[illegible]~~ a mockery of your knowledge by repeat
ing that which forms the preface to almost
every book in the science. — The historical
introductions and treatises so common in
our books and lectures, have always ap
peared to me to be the mere apologies for
thought, the substitution of the wasteful em
ployment of transcribing, for the useful oc:
:cupation of reflection. and even under the
most ingenious and eloquent forms in which
they can be presented, they seem like the
using up of time only for the purpose of
sacrificing it in ~~[illegible] if I may be~~
~~singular on this point, but I must confess~~
~~that I heard this history of medicine so often~~
~~repeated, so much varied in arrangement~~
~~at the whim of each narrator: that all~~
~~systematic connection of opinions, errors and~~

tion, lessens the supply of blood to that source (the heart) from which any plethora caused by that obstruction, must proceed - If the obstruction should be complete no more could be sent on from the heart than the contact of the ventricle, if the obstruction be partial then, the blood will only take on a velocity inversely proportional to that diminution of area - The phenomena afforded by a ligature around a limb afford no proof of congestion taking place from the obstruction of the large trunks, for here the heart continues to be supplied from other sources, and can therefore furnish blood to the arteries for the congestion in the tied veins -

The obstruction of the aorta furnishes no argument against the power of the heart alone to propel the blood through the body

~~persons who confounded, and some absolute~~
~~[illegible] scattered [illegible] remained on my~~
~~mind, of dogmatism and empiricism, of their~~
~~[illegible] Hippocrates and Galen. There~~
~~was a period when I left the University~~
~~[illegible] that I hoped to~~
~~[illegible] and [illegible], but the~~
~~first object I met on the [illegible] of a foreign~~
~~school was the same conjecturing [illegible]~~
~~of repetition in the form of the history of the~~
~~origin and progress of medicine~~ -

Under these impressions it has always appeared to me to be a desirable object in an introductory lecture rather to enquire into those subjects of our art that at ~~[illegible]~~ demand inves=tigation, than to consume both time and patience in framing conjectures on the origin of medicine, or repeating quotations of history long since established, and every

where to be found. But besides the advantage probably resulting from such a plan of procedure. There is an other reason with me not less influential. You know that I propose to read to you the lectures of another. and tho' constantly in the practice of offering remarks on those parts that seem to require further elucidation. and of guarding my pupils against [redacted] what appears doubtful in its nature or authority. still my office precludes me from the opportunity and the freedom of offering any extended views of my own. — I am happy therefore to embrace the occasion now occurring before you, to communicate the result of my enquiries on the subject I have selected for the present lecture.—

It was my intention to give you at this time the result of some observations and reflections I had made on the Pulse, and

vs. the knowledge of

to apply the knowledge thus acquired to the explanation of some of the phenomena, and to the cure of disease. But you are aware that the various forms and modes of the Pulse, properly so called, are functions of the diseased Sanguiferous system - and since the diseased functions of this system are only alterations of its healthy action, it is plain that the healthy action of this system, or as it is commonly called the circulation of the blood should form the basis of an enquiry into the nature and causes of the diseased Pulse. - I will therefore, at present defer the consideration of the Pulse as a symptom of diseases, with the intention of laying before those of you who may attend the practice of the Phila Alms house, the ideas and facts I may possess on this subject, either in the form of a Lecture, or in the more useful and impressive

mode of instruction and demonstration at the bedside of the patient of that institution. I shall now undertake the inquiry into the physiology of the blood especially more particularly of that part which regulates the motion or circulation of the blood, as it is from some original and peculiar views on this subject, that I shall hereafter deduce the causes and explination of some of the phenomena of the diseased pulse. —

The motion of the blood in the human body is carried on thro' a series of parts and organs which have together been called the sanguiferous or circulating System. These parts and organs tho' they possess in common the function of transmitting the blood in a kind of circle of motion, have at the same time structure and actions obviously

distinct from each other.- These parts are the Heart, the arteries, the capillaries and the veins.

The heart is a muscular organ of four communicating compartments, having the power of alternate contraction and dilatation, and furnished with valves so placed between its chambers as to allow a progress of the blood only in one forward direction.- Two of these chambers are called Auricles and two Ventricles. The ventricle by its strong contractile force propels the blood into the extremities of the tubes that arise from it, whilst the auricles being at the same moment dilated and filled as a reservoir by the blood returning from those extremities, is prepared by its contraction to fill the ventricle now emptied and dilating. Thus by an alternate action of the auricle and ventricle is the circulation continually carried on. From

this view it appears that one auricle and ventricle placed in a part of the circuit of the blood path thro' the body, would be sufficient apparatus for effecting the continual circulation, - and that a perfect heart required no more than these two divisions. Why then has the human heart four? To answer this question, it is necessary to remark that before the blood is fit to be conveyed as nourishment to the body by this single heat of one auricle and ventricle - it must in some places part with some of its components, and in others receive some new principle from without. - Thus the blood coming in contact with the external surface of the body and insinuating thro' the kidneys, throws off the perspiration and urine. - Now the separation in these cases being made from a comparatively small portion of the external vessels, perhaps not their hundredth part, the circulation thro' these external vessels is easily carried on by this single

heart, without the aid of any new function or force.- But it is different in the case of the blood receiving a new principle from without, It is a condition of the circulation that the blood should receive some new principle from the air, and a not only that a small part, but that the whole mass should, in a given time, be subjected to its influence.- This requires that the blood be sent thro' an infinite number of small vessels spread on the air cells of the lungs. From this extensive surface of friction a resistance is created, not much less than that which arises from the blood sent throughout the body by the single heart.- hence then the necessity of a second auricle and ventricle or of another heart to carry on this second circulation.- It may be interesting to point out the wise economy of their being thus joined together.- In a single heart as we have been considering it, the ventricle was supposed to return the blood to its

own auricle, hence if this were done by both the hearts, there could be no community in the circulations of the body. But it is necessary that the blood sent out for the nourishment of the body should be the same that has been subjected to the influence of the air by the other circulation. They are then wisely and beautifully joined, by counterchanging as it were, the functions of the two organs, that is by making the ventricle of one heart return its blood to the auricle of the other. -]

It has sometimes been made a question among physiologists concerning the motion of the heart, whether its actitation be an active or passive phenomenon, that is whether the ventricle has in itself an inherent power of expanding, after contraction or whether this expansion is produced by the mechanical effect of the blood pressed into it by the contraction of the auricle. To me it seems extraordinary that in these latter ages of Phy

siology a doubt should exist, since the continuance of motion in the heart when separated from the body and organs of some animals experimentally demonstrates that the ventricle is dilated by a power arising in itself.—

The second part of the circulating structure is the arteries. They are tubes arising from the ventricles of the heart. That run into divisions and subdivisions, till they are distributed in their finest or Capillary branches, throughout the whole body.— It can be shown that the aggregate areas of the subdivisions of any one branch of an artery is much greater than the single area of the section of that branch, and consequently that the sum of the areas of a transverse section of all the capillaries or extreme branches of the arteries, must be greater than that of the single arterial tube as it leaves the heart. The arteries therefore have been said to resemble, in their form a tree whose, springing from the heart, and in their contents, a cone whose

apex or point is at the heart, and whose ca: pacity encreases as its diverging sides recede from it.- This increasing capacity of the arterial tubes as they recede from the heart, necessarily creates a difference in the velocity of the blood that passes thro' them.- For this velocity will be inversely as the area of the vessels, that is in whatever ratio the areas of the branching vessels encrease, in the same proportion will the velocity of the blood flowing thro' them be diminished.- In the extreme or capillary vessels therefore where the sum of these areas is the greatest, it may be shown that the velocity which the blood had at its issue from the heart is retarded to a creeping and scarcely measurable motion.

The coats of the arteries consist of elastic substance, and of a layer of circular fibres, of a yellow or straw color in the larger trunks and gradually changing their texture and hue as the vessels diminish, till they assume the appearance in the smaller branches, of

common muscular fibres - The presence of these fibres in the coat of the arteries has been the cause of much physiological discussion and error. - as it was inferred that the vessels derived from them the power of alternate dilitation and contraction simlar to the heart, and which served to aid that organ in propelling the blood thro' the system. - I hope to prove to your satisfaction hereafter that the arteries do not possess such power; that if they did possess it, the circulation would not be aided, but obstructed by its operation - I shall only remark here that these muscular fibres give a power to the vessels which has been called Tonicity - This tonicity or muscular power produces in the vessels the following effects - It causes a variation in the size or volume of the artery, by its increase or decrease, and this variation is not of momentary alternation like the heart, action but continues in its state of enlargement or contraction for hours days - and even weeks duration. This variation is exhibited

$\sqrt{\cdot}$ or by their values. -

in the changes of the volume of the artery, on exposure to heat or cold, from the influence of the passions, in the cold and hot stage of fever and in many other diseases, as I shall particularly show when I treat of the diseased pulse. Other effects of this tonicity are to cause a permanent contraction of a vessel, when it no longer contains blood; when it is laid bare, or exposed to the atmosphere; when it is cut across or divided, and finally at the period of death. At this time the contraction is so close that most of the blood is propelled out of the vessels into the veins. Some hours after death this tonic contraction ceases, when the elastic substance of the vessel restores the tube to its usual diameter, and the blood that had been propelled out being prevented by its coagulation in the veins from returning, it leaves them in that empty state in which they are usually found after death. — Although I thus deny a momen

tary contraction and dilatation of the arteries similar to the pulsation of the heart, I would not be understood to assert that the arteries are materially in carrying on the circulation. Observations and experiments on the arteries of living animals have exhibited the following varieties in their motions. From the connection of the heart and large vessels with the lungs, the arteries not very remote from them, have a longitudinal motion synchronous with that of respiration. This is sometimes so considerable as to produce an arch or curvature in the length of the vessel. There is an other motion observed, synchronous with the pulsation of the heart and which from that circumstance has been mistaken for the dilitation and contraction of the artery. This is caused by the vibratory motion communicated for some distance along the vessels from the jerking action of the heart. There is also a third motion of the arteries produced by the momentum of the blood driven into them

by the stroke of the heart. For this momentum being exerted against the sides of the vessels at their curvatures and branchings, produces in those vessels, according to their loose or firm attachment to the surrounding parts, more or less of a lateral, or vertical or rotatory motion - and which from its agreeing with the time of the heart's pulsation has been confounded with a supposed inherent power of pulsation in the arteries. - The phenomena here enumerated, and which arise from mere locomotion of the vessels, have all been pointed out and ascertained by the accurately conducted experiments of Doctor Parry of Bath. - The next portion of the circulating System to be considered is the Capillaries. I would not have separated these minute vessels from the larger arteries of which they are the mere continuation had not some of their phenomena induced a belief among some later physiologists that they exerted an active agency in the circulation.

It was observed by Leuwenhoek, Baglivi, Van Heyde, Senac, Haller and other experimenters that the blood in the capilaries did not pursue a uniformly direct course, but that its currents were promiscuously forward and retrograde in contiguous vessels, and in the same vessels at different times - it was observed too that irritation made on these vessels caused reverses and opposite currents in them - and these phenomena were ascribed to peculiar properties and functions of these small vessels, quite different from those possessed by arteries of a larger size. But these appearances all flow from the innumerable inosculations or connections that exists in the capilaries. for from such a construction, any contraction or dilatation of these small vessels produced by an obstruction of their canals or by irritation from without, would cause the blood indifferently in any direction - It was further remarked of these Capilaries that in certain particular diseases they were so distended with blood as to cause a visible red

v. It was observed too that the blood some times moved onward in these small vessels, after the heart had ceased to beat.

ness on the surface. and under the influence of certain passions they were seen to be converted into palsy and enlarged to suffusion. vi.
These facts seemed to point out an active and peculiar function in these vessels - But from what I said on the subject of the Tonicity or the permanently contracting and dilating power of the larger arteries, you are prepared to understand these appearances. The capilaries then do possess the same tonicity as these, and the facts in question proceed from the same function of the large arteries continued to the smaller, and perhaps it is exerted as frequently in one as in the other, But the variations of the dimensions of the larger tho' measurable, are not so often or readily perceived, whereas the capilaries of the skin exhibiting their contained blood thro' their transparent coats, do sensibly and quickly shew by their color when the volume of that blood is increased or diminished. —

From this view of the facts it appears to me that they do not admit the inference that the capillary vessels possess any active and peculiar agency in the work of the circulation.

The last portion of the sanguiferous system is the veins. These like the arteries have been compared to a tree whose root is fixed in the heart. and like them too, their capacity increases as the branches multiply and close in with the capilaries of the arteries. [There is however some difference between them. In the small or capilary vessels of the veins and in the trunk near the heart, the areas are about the same with the corresponding parts of the arteries - But the capacity of the extent of the veins within those limits, exceeds the capacity of the same relative extent of the arteries in the proportion of more than two to one. This proportion expresses the relation of the capacity of the whole of the veins to that of the arteries But there are some particular parts of these

two systems in which the ratio of the capacity of veins to arteries is much greater. Thus at the bend of the arm, there are five veins returning the blood ~~from~~ conveyed by a single artery whose diameter does not exceed that of any one of those veins — The veins are provided with valves which allow the progress of the blood in but one direction from the extremities — They have more elasticity than arteries, hence they allow greater distention and readily return to their usual size when that distention is removed. — They ~~do~~ possess a Tonicity similar to that ascribed to the arteries tho' in the veins it produces a variation in the size of the tube, perhaps less frequently, and certainly with less force. — That this tonicity exists in the small or capilary veins, must be inferred from their closing to blud equally with the arteries, a short time after they are divided — and its existance in the larger veins is palpable, in the variation of the size of these vessels, so frequently occurring in

v. from their contraction

v. The detail and manner of its motion were still unknown for Harvey only pointed out its path.

v The greatest human sacrifices that have been exhibited to ~~set before~~ the world have been made for the service of man kind -

diseases, and indeed evident on the application of cold to the surface of the healthy body. Such are the mechanical structure and conditions of the channels thro' which the blood circulates in the human body. It remains for me to show the manner in which the action of that structure produces the circulation. — It is now almost two hundred years since Dr. William Harvey demonstrated, in opposition to former opinion, the motion of the blood to be in circular returning current thro' the body. — It was for one man perhaps a sufficient contribution to the light of science to uncover this blazing truth — a truth which while it drew all eyes by its benefits, prostrated all gratitude by their immensity, and Harvey in thus setting his light on the altar of usefulness was the first offering to be consumed by it — The man who makes a discovery advantageous to humanity is often too much employed in contesting with the enemies his greatness has

created to have the full prospect and to make all the applications of his truth. and Harvey pres'd into the impotence of poverty, by persecutions - was obliged to leave to his successors the completion of a work he had undertaken but which he had not the means or time or encouragement to fulfil -

Since the time of Harvey different explinations of the circulation have been proposed, and it may seem strange that a subject so open to observation and experiment, should yet be obscured by difference and doubt. - I shall mention one or two of them, with the objections against them before proposing that which has arisen in my mind as an induction from the structure and phenomena of the circulatory system -

The first opinion on the circulation that arose in the school of Harvey, and which is held by many at this time, was that the contraction of the left ventricle, discharged about two ounces

of blood into the artery. The addition of this quantity to vessels already filled, caused a dilatation of their sides throughout the whole arterial system. In the succeeding moment when the heart began to dilate the arteries being no longer propped by the entrance of blood, began in their turn to contract and the valves at the heart preventing its return into that organ it was driven forward into the veins, and thus by the alternate stroke of heart and artery, the motion was effected in this first section of the circulating system. — according to this opinion it was continued in the veins, by the force of the arteries behind, by an absorbing or suction power in the capilary veins, by a slight contraction of the veins themselves, and by the pressure of muscles upon them. — There was indeed some plausibility in this solution considered as an early trial of enquiry The sensation of a shock on pressing an artery, being such as might arise from a sudden enlargement, the visible motion of superficial vessels, and the supposed necessity of an aid to the heart, to

overcome the resistances of the blood, were cer-
tainly facts that might have led without much
reproach of reasoning to the false inductions
founded upon them. - This explination however
will be found inadmissible, on a close observation
and comparison of the phenomena of the circulation
It is assumed in this view that the heart alone
cannot overcome the resistance of the vessels to
the blood, and hence the necessity of the pulsation of
the arteries - Without rejecting this as mere hypothesis
it may be asked if there is any gain to the heart
in thus adding to the resistance of the weight of the
blood and its friction on the vessels, in adding I say
to these, the further resistance of distending the thick
elastic coat of the vessels throughout their whole ex-
tended surface - But admitting even this, and that
the artery after being distended contracts upon its ac-
cumulated contents it is plain the force with
which it contracts must be less than the heart
or it must be be the same or it must be grea
ter. - If it is less there is a positive loss, by the

V. is by arising the

V. Has the heart force during the contraction of the artery, when by supposition the power of the artery exceeds that of the heart. –

heart expending a greater force in distending the artery, than it receives in return in its contraction - If it be the same, there is no gain, and if the arteries contract with a greater power than the heart, how does it happen that on the division of an artery, the jet or momentum of blood is greater during the expansion of the artery, or the time of the heart's action, than during the contraction of the artery, by which supposition exceeds the force of the heart - But further if the arteries are distended by the blood from the heart, it must be because the blood does not pass out at the capillary extremity or that it passes out slower than it is received, in either of which cases there would be a greater or less pulsation perceived in the veins - and yet the motion in the veins is of one uniform current. Again the arteries of the whole body if extended superficially would occupy a space greater than the surface of the skin. Now it must be evident that if the two sums of blood, thrown into them and which are supposed to cause their pulse, were spread on this

surface, it would not cover a fourth part of it with a stratum of the least measurable thickness. How then could the two ounces when thrown into the arteries and spread throughout them, produce a sensible or effectual dilatation in them.—

This last objection having been admitted as an insuperable argument against the doctrine of a general dilitation and contraction of the arteries, an other attempt was made to solve the problem of the circulation by considering the action of the artery as partial, Some physiologists then acknowledging that the two ounces projected from the heart, was not sufficient to distend the whole of the arterial system at once, to any sensible dimension - asserted that this quantity of two ounces might produce the requisite enlargement throughout a certain extent of the artery, suppose twelve inches from the heart, this portion then contracting, propels part of its contents, into a second portion of the artery of a certain extent, and thus by a succession of these pulsations of limited portions of the

v. stanas in a logical point of view -

arteries continued to the extremities of the capillaries the blood being obstructed by the valves at the heart from returning was carried forward to the veins - It was in short making these successive portions of the artery, so many cylindrical hearts, only having no valves between them [illegible] In reviewing this rationale of the circulation I need scarcely tell the youngest of you that it is altogether an hypothesis, for what observation however marked and inaccurate could mark the motions on which it is grounded - It may perhaps be regarded as merely one of those schemes, so common in science, for the developement of subjects on which knowledge is both desirable and deficient. - [illegible]

5. It is assumed in this theory that whilst the ventricle is contracting the first portion of the aorta is dilating to recieve the injected blood. Whilst the ventricle is in the pause of its dilatation this first portion is contracting and the second portion of the aorta is dilating to recieve the blood pressed on by the first portion, so that

~~or discriminate, there is no appearance between them as to the first, for if the dilatations of the successive portions of the arteries from the heart to the extremities be all made in that single part of time, in which the left ventricle contracts it would be impossible for the eye or touch to distinguish any priority in the time of these successive pulsations. — The whole would therefore appear to be one instantaneous dilatation & these observations can furnish nothing as the basis of this opinion,~~] But even as an hypothesis it will be easy to show that the operation of the proposed scheme would produce effects very different from the real phenomena of the circulation. — v.

[~~If a cylindrical tube whose sides are unyielding be filled with a fluid, and an additional quantity of fluid be pressed into one end, at the same apparent instant an equal quantity will flow from the other extremity whatever be the length of the tube. — For since the admitted quantity can not enter but by the~~ space afforded by the ~~discharge of an equal bulk~~

the ventricle and the second portion are both in dilatation at the same time, whilst the first portion and the third are contracting at the same time - and as this alternate action is continued to the end of the arteries, the progression of the odd numbers of these sections will be in a state of dilatation, at the time the progression of the even numbers are in a state of contraction, and thus contiguous portions will therefore in their actions, resemble the alternate action of the auricle and ventricle of the heart. - Since therefore there is as much of the whole extent of each in the state of contraction as the reverse, it is impossible there could be that universal synchronous stroke that is felt in the arteries. - But further there is a fact on the subject of this synchronous stroke that points out more precisely the utter impossibility of such a succession of action in the artery as the theory supposes. - It has been shown by the detail of this theory

It appears the motion of the added quantity is the cause of the motion of that discharged, and a reason can be given why the velocity of the first moved by it be increased or decreased in its own proportion, it follows that the velocity of the two quantities must be equal, and the same will be true of all the intermediate quantities of fluid for if it were otherwise, there would be a compression of this intermediate quantities or a dilation of the cylinders, which by the supposition of the proposition are impossible - The velocity and space described by the whole fluid will be measured by the velocity and space of the added fluid quantity. The motion of fluids or it is analogous to the motion of solids, i.e. to the motion of the solid collection of fluids, because in them there is no alteration of the relative position of particles, but only absolute motion of the whole. But the case is different with fluids flowing thro' distant tubes, for here if the resistance to the discharge be greater than the resistance of the elasticity of the tubes there will be distended on the admission of any new

that when any one of these limited portions of the artery is in a state of contraction and propelling its contained blood, the next portion in advance is at the same time dilating to receive it, as they then exactly resemble both in the mode of their motion and their effect the auricle and ventricle of the heart, we may take the terms of auricle and ventricle as convertible with those of any two portions of the artery, so that the whole of the arterial course will represent an alternate series of auricles and ventricles. Recollect however that I make this substitution of terms and this analogy only to afford an easier comprehension of the argument. — Now suppose ten auricles and ten ventricles thus alternately continuous with each other. It is plain that the blood cast on by the contraction of the first ventricle cannot reach the tenth, till it has successively undergone the contraction of the eight intermediate ventricles, that is the blood cannot reach the tenth ventricle, until the time occupied by eight

quantity of fluid, the space is given equal to the
bulk of that received, and no discharge will take
place and thus the motion will not be of the solid
column but of the particles composing that column
whose relative position will be changed by lateral
space
and other motions to fill up the yielding [illegible]
of the tubes. — Now to apply this to the hypothesis
before us. When the heart projects its two ounces of blood
into the first portion of the aorta which we have
set at twelve inches, the sides of the tube are distended
and by a space capable of containing this additional
quantity, and none is discharged from it, and more
is sent from the heart, upon the contraction of this
portion of the tube equal to this addi-
tional bulk received is discharged from the end re-
mote from the heart, into the second portion or sec-
tion of the aorta, this second section performs the
same action and discharges the blood into the third
and thus it is carried thro all the succeeding
sections, which continue distending in length the
as they approach the veins. For as it is the
quantity of blood thrown into one of these sections

succesive contractions will have elapsed - and the same will happen if there should be a pause of the first ventricle, and no blood should be cast out. - That pause or that deficiency of blood will not be felt by the tenth ventricle till the time of all the intermediate ones has elapsed. - If instead of the tenth the sixth be taken it is evident that the time in which the pause will be perceived in it will be less - so that it is impossible that the pause can be felt at the same time in any two different ventricles. - Now in the circulation of the blood the heart occasionaley suffers such a pause as we have been supposing, on such occasions I have proved with the aid of an assistant, as any of you may prove by like observation, that the pause is felt in all distances of the arteries, in the carotids at the ancle and at the wrist, at the same instant of time - a theory therefore that contradicts a manifest phenomenon of the circulation cannot be true

that arteries is length, it follows that in
the capillaries, where the quantity is the least capable,
the length of the section will also be
least of all, there will be an immense
number in the whole distance from the heart
to the veins. But I am willing to take only twenty
of the sections, and they may be proved for more nu-
merously as the elements of a calculation now
as the motion of the blood from the heart to the vein
and the sum of these 20 successive sections is all effec-
ted in the time of the discharge of the two ounces
from the heart, it is plain that the motion of
one of these sections is effected in a twentieth
part of that time, that is, the velocity of the dis-
charge of blood from the end of any one of
these sections is to the velocity of blood at
from the heart as 20 to 1. But who does not
see that the momentum resulting from such a
velocity of the blood would be utterly destruc-
tive to the system, when it is so constantly found
to tumble or treble the ordinary motion of

~~The motion of the heart is accompanied by [illegible]~~

Having thus stated the two prevailing opinions on the subject of the circulation, and given as I hope satisfactory objections to them, I shall now offer that which I shall be shown both to have its foundation in observation, and to furnish admissible explinations of the phenomena.

I begin by remarking that the heart is the sole cause of the motion of the blood thro' the vessels. The motion of the heart ~~may be~~ was seen and felt, and its power has been proved by experiments, No objection, therefore to its being the sole cause of the motion of the blood, can be admitted, but those that shew that it is aided by some other power. The aids to the heart were supposed to be shown in the dilatation and contraction of the vessels, the suction power of the veins, and the pressure of the muscles upon them. On the first of these points, the pulsation of the vessels, I have already shown a priori that no such pulsation could take place

from the operation of its supposed causes, But I do not wish my argument should rest on this alone. It has been proved by observation and experiment that no such dilatation and contraction of the arteries does exist. — It has been admitted by Haller even tho' he ascribes the pulse to the dilatation of the artery, that the inspection of the ~~arteries~~ veins of living animals frequently exhibited no sign of their alternate movement. Bichat afterwards denied altogether the existance of this dilatation and ascribed the pulse to the motion of the whole artery, or what I called in the speaking of the arteries, their locomotion. — But the full establishment of this opinion has lately been effected by Doctor Parry of Bath by an ample series of the most precise experiments. — Doctor Parry has given the history of 27. different experiments made with a view to discover the functions of arteries in living animals. In these opened by his medical friends he exposed, different vessels, and tho' they all employed the most attentive observation as well as used some modes of mechanical

v. analogies in nature are not wanting, to warn us of the problematical nature of this assumption which seems to be grounded solely on the idea of the necessity and universality of attraction, - The appearance repulsion or at least the want of attraction between water and the leaves of some aquatic plants, shows us one of these analogies. May the polished coat of the cornea be another of these

Surface?

measurement, they were unable to detect the least dilatation or contraction of the artery. - There was no exception here from the exposure of the vessels, as the pulse was felt on pressing the vessel as sensibly as before it was laid bare. -

We see then no possible foundation for the opinion that the arteries afford any aid to the heart in carrying on the circulation. The idea of aid being derived from capillary attraction in the veins, or as it is called their suction power, is equally unsatisfactory. In the first place as it is said to take place in vessels too minute to be the subject of observation or experiment, the existance of this capillary attraction between the internal coats of veins and the blood is entirely an assumption. - But allowing its existance it is easy to see it must be an obstruction to the advancement of the blood, but it cannot without an absurdity be supposed as a cause of its progress. With regard to any aid from the muscles by their pressure on the veins, during their action, I would only observe, that this cause if it were

v. Thus if a cylindrical tube whose sides are unyielding be filled with an incompressible fluid, and an additional quantity be pressed into one end, at the same appreciant in-

effectual could be so only occasionally, and therefore discovers no consideration, in an enquiry after the continual causes of the circulation. As no cause can be shown to afford aid to the heart, it remains for this organ alone to carry on the circulation. The sufficiency of its power I hope to make manifest in

As the action of the heart is exerted in producing motion in a fluid, it will be necessary for the understanding of what I deliver, to explain to you a law of moving fluids. — Fluids from their consisting of particles easily moveable among one another, and possessing little mutual cohesion are capable of two kinds of motion, the one a motion of their whole mass in common with solid bodies, the other a vibration or undulation of the particles themselves, communicated successively from one to the other throughout the whole mass. ~~Thus if a solid tube cylindrically and [illegible] a fluid in at the upper end it will quickly pass through and be discharged at the other, here there is a motion and sensible velocity of the whole mass.~~

stant an equal quantity will flow from the other extremity. For since the admitted quantity cannot enter, but by the space afforded by the discharge of an equal bulk it is plain the admitted quantity, is the motion of the cause of the motion of that discharged, and as no reason can be shown why the velocity of the first should be either increased or diminished during its communication, it follows that the velocities of the two quantities must be equal, and the same will be true of all the intermediate quantities, for if it were otherwise there would be a compression of the fluid or a dilatation of the cylinder, which by the conditions of the proposition is impossible. This motion as it is analagous to the motion of solid bodies, is called the motion of the solid or continuous column of fluid -

But if the same tube be filled, and each end be covered with a piece of leather, a blow or shock given to one of these pieces of leather, will be felt in the same appearant instant, by the finger applied to the other. Now this exhibits and illustrates the vibration or undulation of the particles of the fluid, for in reality each particle of the fluid does go forward and return thro' an infinitely small space, and this vibration being continued on to the end of the tube does there, by the forward motion it gives to the last stratum of particles impress the finger with the pulse that is felt. - Tho' it is true that fluids when acted on press in all directions yet in this case if the tube be rigid or undilatable there will be no lateral vibration, for since all vibration requires space, and since no lateral space is afforded by the permanent diameter of the tube, it follows that the longitudinal vibration or undulation is the only one that can take place or be felt in the tube. - Now tho' these vibrations are positively momentary thro' space, yet the spaces are so small or the times so quick, that they produce no visible velocity in the particles of the fluids that are in the middle of the tube or that are surrounded by

v. Or let the leather be taken from the extremity, the particles at the end of the tube leaving nothing that they may impart their motion to

other particles, but let the advanced particle be at any place removed, ~~to remaining particles having room~~ to expand themselves, will now be carried off from the mass with a visible velocity. The same would take place if the sides of the rigid tube which allowed no lateral vibration were to be opened, for space being thus afforded for a lateral vibration the particles at the aperture would be carried off with a visible velocity. — A familiar illustration of this may be given you by the action of a series of ivory balls. — If any number of these be suspended in contact in a line, and the first be struck the last will in the same apparent moment fly off with a visible velocity, whilst all the intermediate ones will remain apparently at rest, tho it is certain they have possessed all the motion the last exhibits, but for so short a time as not to allow a visible velocity. — To apply these remarks to the circulation. Let us suppose the heart and blood vessels filled and that the left ventricle contracts, two ounces of blood will thus be driven into the aorta, The arteries being unyielding tubes, at least not

v. and all the intermediate quantities of fluid will move forward with a velocity inversely proportional to the capacity of the vessels thro' which it flows. —

being ~~a~~ dilatable by this blood thrown in, the mo
of the blood in the arteries and veins will be ~~that~~ of
the solid column spoken of before, that is when
the two ounces are added to the arteries by the ven
tricle, two ounces will at the same appearant time
be discharged from the veins into the right auricle
~~[pass since the artery and the vein at the heart
have nearly the same capacity, if we suppose the
two ounces of blood to pass into and occupy four
inches of the first portion of the artery, four inches
of the vena cava will be emptied in the same
time, and the portions of the tubes between these~~ two
~~extremes, will be pass'd over in time,~~ inversely proportioned
~~to the increase of the areas of the tubes as they ap=
proach the capilaries, thus if we suppose~~ the areas
~~of all the capilaries to be to the area of the~~ aorta as
~~50 to 1 which is the least it can be, then in the
same time that the mass of blood in the aorta or
veins is passing over 4 inches, that in the capilaries
will pass over but the twelfth part of one inch~~]
This motion of the solid or continuous column of
the blood by which it is made to change its place

continually in the vessels, is not the only effect pro-
duced upon the mass of blood by the heart,
When the ventricle contracts forcibly on its contained blood
the solid sides of the cavity of the ventricle impart
a shock to the blood, which like the blow impressed
on the leathern in the instance of the tube above
mentioned, causes a vibration or undulation that
is sent out instantaneously to all parts of the
fluid, diminishing however as is the case with all
fluid undulations, in proportion to its extent.-
Thus the heart produces two manifest effects on the
blood by its contraction, first a comparitively slow
motion of the whole mass, and secondly an immeasurably
rapid undulation.- It is the last of these that con-
stitutes the Arterial Pulse, I have already proved to you
that the throb or pulse of the arteries is not produced by
any dilatation of the sides of the vessel, It only remains
on this head to enquire if the Pulse may not be occa-
sioned by the progress of the mass of blood along the
vessel contradistinguished from the rapid undulation.
The only manner in which the mass of blood could
produce the sensation of a throb or pulse would be

by flowing by jets or by an alternately increased and retarded velocity, thro the vessel. But I shall prove to you presently that the blood does not flow in this manner, but in nearly as uniform current as it does in the veins - I will only observe here that if the mass of blood moved by jets in the arteries the same species of motion would be seen or felt in the veins for the blood in the arteries and veins being one continuous column, and that too moving in the same circle, the kind of motion in one must also be found in the other. without contrary reason can be shown. Now this contrary reason is supposed to be shown in the increasing area of the arteries as they approach the veins - for it is said the blood flowing rapidly in the large vessels, it produces there a blow or throb which is felt as the pulse, but in the smaller arteries the velocity is so much diminished as to prevent the blood producing any sensible impulse - This idea is opposed by the phenomena of aneurisms, for here there is an increase of the area of the vessel by its distension, and consequently a reduction of the velocity of the blood, and yet we know that the throb or pulse, so far from being obliterated or lessened

V. again, if it is the velocity of the blood that causes the sensation of the pulse, how does it happen, that when an artery is completely obstructed by a ligature, there is a pulsation and an increased one too, just behind the ligature, where by the very condition of the parts, there can be no velocity of the blood. —

in the sack of an aneurism, is generaly much encreased in its force beyond that of the pulse of the smaller artery leading into it — This fact is entirely consistant with the principle of the undulation I have laid down for if the pulse be produced by the rapid flight of this undulations from the side of the ventricle to the capilaries, or perhaps beyond them where it dies away, then I say it will pass with equal velocity whether the space of vessels thro' which it moves be contracted or enlarged — and in some enlarged part of the sack of an aneurism, the undulations spreading in all directions thro' its contents, will give from the greater bulk of fluid set in motion, a stronger impulse on its sides being prest. — But further that it is not the velocity merely of the mass of blood paping under the finger that creates the pulse that is felt is evident from this, When it beats from 130 to 60 in a minute it is certain the velocity is about its greatest, and yet every practitioner knows that these rapid pulses are seldom strong the strongest are generally when the pulse is from 50. to 90 when the blood is at its best velocity, and for it is in

these cases, that the pulse is often felt as if it were the shock of a solid body contained in the vessels. for you can readily understand that the whole mass of the blood may move slowly from obstruction somewhere existing, and yet at the same time that the heart may make a stronger effort on its contained blood in consequence of this obstruction - Now it is this strong effort or jerk of the heart on the blood, that sends out the undulation that constitutes the pulse even tho' the whole mass move very little may so widely may these two motions in the arteries of the mass of the blood, and the rapid undulation sent out, be distinguished from each other, that I hope at some future period to show you when beating of the disease pulse, that in some of those affections of the heart and its valves where the pulse has its greatest fulness and hardness and resistance, the whole mass of the blood is propelled with a mere creeping progress, if indeed it be not on some occasions brought for a few moments altogether to a pause. — I asserted above that the blood moved in nearly as uniform a current in the arteries as in the veins - I have anticipated your surprise, if not your immediate negatives, on an

opinion so directly opposed to a doctrine universally received and which as far as I can learn has never until this moment been even questioned. - I advanced above an argument that I have given under a different aspect when I say that in a shell of one continued line or column such as the blood in the arteries and veins, and where the motion of the second half of that column is derived wholly from the motion of the first - I say it is at once inconceivable that the motions should not resemble each other in kind - If a certain quantity is added at one end an equal portion must pass off at the other: and if this quantity be added to the first portions of the aorta by a jet, it must fly off from the cava at the other end in a jet. - But it does not fly off from the cava into the right side of the heart in a jet, as may be seen by two remarks - First from there being no valve between the cava and the auricle, the cava having filled the auricle continues still to propel its blood into the auricle, whilst this last is propelling its contents into the now dilating ventricle. - For tho' the auricle does press strongly on its blood, yet the vacuum of the ventricle soliciting and something its easy flow in that direction, the pressure

of the auricle must give it a velocity in the way it is least resisted so that a slight momentum of the blood of the cava will continually carry it into the auricle. - Secondly if the blood of the cava be discharged by a jet then all the blood of the veins behind it must also have an alternate retardation and acceleration which we know is not the case. - I conclude therefore that the blood in the arteries does not move by a jetting current. - But I will go further with this question and ask from what facts in the phenomena of the circulation, this supposed alternate quick and slow motion of the blood in the arteries is inferred, - They are three. The sensation of a jerk or pulse in the artery in which it is said the current pipes with a greater velocity under the fingers. 2d. The alternate fortnes and meases set on the division of an artery. 3d. The alternate motions said to be seen in the capillaries, and 4th. From the blood being driven into the artery by the heart, in alternate gushes, it is inferred that the same gushing must prevail the whole arterial course. - In answer to the first I hope I have shown you that the throb felt in the pulse is not produced, by the mass of blood in the vessel

passing quickly under the finger, but by the blow or shock of the side of the heart on the surface of its contained blood, causing out an undulation that in an apparent instant spreads thro out the system and to give you a familiar illustration, just as, the blow or shock given to one side of the abdomen of a dropsical patient, communicates in an instant undulation or pulse to the hand applied to the other in which case it is certain the mass of the fluid has not changed its place. - its particles only having in succession each, given a thro' infinitely small space, and thus communicated the impetus or shock, precisely as sound is communicated thro' the air. - With regard to the second fact it is thought that as the blood flows from a cut artery, with an alternately quick or and slower leap, it must necessarily have the same variable motion within the vessel, but a little reflection on the phenomena will teach us that the inference is not just. From what I have said of the fluid undulations, you have understood, it is a motion of the particles, communicated to the fast

5. If then from the greater of the two jets exhibited on the admission of an arbitrary, the velocity given by the undulation, ~~and added to the other~~ be subtracted, some of it will shown not to exist in the vessel, it will reduce these impulses to an equality -

icles next before them, just as motion passes through a series of ivory balls and as in the line of balls that have others before them, remain stationary, when as the last one having none before it in which it loses its motion flies off with a visible velocity, so the undulation in the blood when it arrives at the last particles, in the end of the divided vessel, causes those particles to fly off with a sensible velocity, but had the continuity of the column of fluid been preserved, those same particles would insensibly have given their motion to those before them. — The unequal motion then lose when a vessel is cut by no means proves the same unequal motion existing in the entire vessels. Upon the third point that the jet or unequal motion has been seen in the capillaries, I have to answer that no such motions can be distinguished by the naked eye in the issue of blood from divided capillaries, and if it be perceived by the microscope it must be from the faint undulation of particles reaching those vessels - and from a magnifying of the motion as well as the bulk of those particles, which otherwise would have been invisible. — Upon the fourth point

or that the blood moves unequally or by jets through
the arteries because it moves unequally or by jets from the
heart. I remark that if this jet from the heart be taken as the cause
of the unequal flow, the
~~motion~~ argument ~~[illegible]~~ would show that the
times of motion should exactly resemble each other
but this is not the case since for more than half
the time there is no discharge of blood from the heart,
consequently at that time or during the expansion
of the heart there would be no motion thro the
arteries, but since there is a continued
~~the is not the case~~, flow thro the arteries,
the pulse being only when it is quicker at one
time than another, it remains to be shown by what
~~other~~ means, it is ~~strongly carried on at all,~~ the
~~regular pulse of the jet of the heart, which is known~~
~~to be the fact, but that it should be~~ carried on at
during ~~the stoppage~~ the pause of the heart as I have asserted with
the same velocity as during the ~~[illegible]~~ ity contraction.
When the heart projects its two ounces of blood
into the aorta with its known great velocity
there, it communicates the same momentum
to all parts of the column of blood between it

ana the termination of the cava at the right side of the heart. But it is known to you that the whole mass of blood having this momentum it will not be lost the moment the heart ceases to act, but will carry on the blood when the heart is at rest. — But you will say that tho' there is a motion of the blood from the acquired velocity yet this motion is diminishing — I answer that this would be the case if the resistance to the progress of the blood were the same during the action and the pause of the heart, but it is different the blood sent on by the action of the heart, is opposed at the other ena of the column by the closed valves of the right ventricle, and by the mass accumulating with considerable resistance in the auricle before it — The blood sent on by the acquired velocity during the pause of the heart, so far from being opposed by these resistances, is solicited on or drawn on by the vacuum formed at the other ena of the column by the dilatation of the

right ventricle, thus the velocity acquired at the pause of the heart, continues undimi-nished, tho the filling of the ventricle begins to arrest it; but at that same moment a new contraction of the left ventricle, revives the motion and thus gives rise to one unvaried velocity. — The same reasoning here employed on the subject of the larger circulation thro' the body, applies equally to the motion of the blood thro' the lungs, for the same relative function of supply and of ventricle and auricle exists here. Let us then recapitulate in a few words the doctrine that has been delivered. — By the action of the heart alone the blood of the whole body is put in motion, the motion thus produced is equable through the entire current of arteries and veins, the two ventricles being the only part where any inequality or jet exists. At the same moment however that the heart gives its impulse to its contained blood, a shock is given by its sides to

the blood that sends out an undulation ~~that~~ which
spreads in an appearant instant thro' a certain
extent of the vessels - for you are to recollect
that this undulatory impetus is in its nature pe-
rishable after a certain extent, as may be seen
in the circles that form on the surface of water
from the shock of a stone cast into it, - Now
in the blood vessels, the extent to which this undu-
lation reaches will be measured by the force of
the shock given by the heart, In those cases of
near approach to death when the heart beats
faintly, it is often manifest in the vessels near the
heart, but lost in the extremities, tho it is cer-
-tain the blood is still flowing thro these extre-
mities - Again when the heart beats strongly
it may reach into and even beyond the capill-
aries - as observation has frequently detected the
jet in the issue of blood from the veins of the
foot, under circumstances, as Mr. Hunter has re-
-marked, that did not allow the possibility of
its being caused by the pulsation of any contiguous

V. but which gives no sensible velocity to the blood thro' which it moves —

artery - The whole motion of the blood has these two aspects, one uniform progress of the entire mass round the circle from the left to the right ventricle, and superadded to this, an alternate undulation that rapidly outstrips this current and dies away in the capilaries. It is the longitudinal slight arc wise of this undulation, that gives the impression of the pulse when the finger is prest upon the artery. - and it is the same impulse that meeting with the opposition of the curvature or branching of vessels, gives rise to the locomotion or change of position of the whole artery that has so long been mistaken for the dilatation and contraction of its sides. For you are to understand that the sides of a straight artery being parallele with the direction of slight of this undulation, no impulse will be felt on slightly touching the bare artery, but the moment the sides are prest in, or a curvature opposes that parallelism is destroyed, and the sides being now opposed to the track of that undulation

will feel a shock or pulse proportional to the direct opposition that is made by such imp: velocity or curve. —

Having in the preceding view ascribed the motions of the blood to the sole agency of the heart I shall here answer the objection that has always been made to this opinion, It is urged that the resistance from the friction of the blood on the surfaces of the innumerable vessels, and from the weight of the mass of blood itself to be moved, is such that the power of the heart alone could never overcome it — In estimating the probable amount of the resistance from these causes I shall consider the human body, in its two different states of an erect and recumbent position In the erect posture the blood in all the parts above the heart is moved against the influence of gravity in the arteries, and in its direction ascending thro' the veins — In the parts below the heart this order is reversed by its ascending thro' the arteries and veins against gravity in the veins — whilst Boerhaave

both above and below there is a similar resistance from friction.- But in the parts below the heart, neither the resistance from friction nor the gravitation of the blood in the veins, is felt or to be overcome by the heart.- For since in these parts, the blood in the arteries and veins is one continuous column, the quantity of blood in those two sets of vessels would balance each other if the tubes in which they are contained were of equal height, - but the arterial tube rising higher than the entrance of the vena to the heart, and ~~not being kept constantly full~~, the weight of the arterial will exceed that of the venous stem, consequently there will be a sinking of the first and a rising of the last to maintain the equilibrium but the longer stem of the arteries, being continually filled by blood from the heart, there will be a continual rising of the column

V. Upon the principle here laid down, we may see a cause of the easy progress of the blood thro' the lungs thickened, and apparently obstructing circulation of the liver. —

in the veins simply from the greater weight of the arterial column. So that the weight of the blood and the resistance of its friction are both overcome in these inferior parts, by gravity alone, with no further aid from the heart than its constantly keeping the higher portion of the arterial stem full. — In the erect posture therefore the greatest labour of the heart will be to propel the blood against its gravity thro' the arteries of the superior parts of the body and to overcome the resistance of friction there. Hence we find those animals, whose heads are always or usually carried erect, have the heart placed near it, whilst those in whose the head is on the horizontal line, or below it, have the heart seated never the ~~centre~~ middle of the whole length of body. — In the recumbent posture of the human body the aid that gravity had given in overcoming the friction of the blood in the parts below the heart is now ceased, and the whole of this resistance is thrown upon the

heart, But it will be seen that tho' the heart is thus burdened with a new obstruction in the recumbent posture, it is at the same time relieved from the labour of sending the blood against its gravity to all the parts above the heart — tho it still has to encounter its friction there — as in this position there is little or no gravity to overcome it appears that friction alone is the obstacle to the recumbent circulation, and whether this or the erect position offers most resistance to the heart resolves itself into the question whether the resistance of the gravity and friction of the blood sent to the parts above the heart, be greater or less than the friction alone of the blood sent to all parts of the body. This is I believe one of the unanswerable questions of Physiology, but it would seem probable that the resistance of friction throughout the whole body or the recumbent resistance was the greater, and that probably from

5. It appears then that the friction of the blood on the vessels is the principal if not the greatest resistance to the action of the heart. and the question is whether the heart is able to overcome it, Now there exist no elements on which a precise calculation can be framed, of the power of the heart and the weight of this resistance, it is impossible therefore to make a strict comparison between them. - or to found a judgment immediately upon them, they must then be rejected from the argument, and their relationship sought by more collateral means. - Now since the heart does exert a force in circulating the blood - and since no other cooperating cause or causes have ever been shown, the inference in the present state of our knowledge must be drawn that the heart alone is sufficient for that circulation -

this case arises the full and slow pulse, and the frequently obstructed circulation of the horizontal position and of sleep. — The effect of muscular exertion I shall show immediately has no part in that alteration. — V.

Upon the view I have just given of the gravitating influence of the two vascular columns of blood in aiding the motion of that fluid in an erect posture, we come to the knowledge of the use of the valves that are placed throughout the greater part of the veins. — The valves have been supposed to aide in the circulation of the blood, by relieving the pressure of the column of blood in the veins, by preventing a regurgitation, on any obstruction taking place, and as they are found in most abundance in the extremities they were supposed to have an intimate reference to the action of the muscles upon the veins. — But these ascribed uses must be rejected upon an investigation, For

since the blood flows uniformly in the veins
the valves must be always open and hence
can oppose nothing to the weight of the col
umn of blood. — nor can they even be closed
without producing an obstruction and an
accumulation behind which if it continue
any length of time will be back'd to the heart
itself — Nor is any thing gained by their presence
under Muscular action. — When a vein is prest
by a muscle the blood is arrested in its passage
thro it, an accumulation takes place behind
which will be the same whether there be
valves or whether they be insurmountable, for
the accumulation takes place not from the
blood prest backward by the muscle, but
from the fresh streames arriving from the
arteries. and the presence of valves can in no
way alter the impetus or quantity of these —
In order to make you sensible of the uses —

vs the importers of

of the valves it is necessary to recur to the fact that when the body is erect, the blood in the arteries and veins forms two upright columns communicating ~~as~~ below. It is plain to you that as these columns of fluid have considerable weight and mobility if a shock is given to the body in a vertical direction, an impetus must be communicated to these columns which will cause them to press on or move in that direction with a force proportioned to the degree of the shock. If there were no valves in the veins, and an impetus were given by running leaping or any vertical motion of the body the ordinary and regular current of the blood would be broken and impeded by the powerful play of the motion of these columns. But the column of fluid in the veins ~~from their capacity being~~ ~~the part of the arteries~~, ~~the preponderance~~ in its descent will be against that of the

arterial column and this last being encreased by the accession of more blood from the heart, an accumulation would take place injurious to its motion and structure - But let us suppose valves to be placed in the course of the venous column, and the ascending column of this column will be destroyed, while that of the arteries remaining, and far exceeding the new weight of the other, the blood will be driven on with an accelerated velocity up the usual channel of the veins - and this is the reason that running leaping, and other excessive violent shocks given to the body are always attended with an encreased circulation - It is commonly supposed that the muscular motion producing these exercises is also the immediate cause of this rapid motion of the blood - But you cant fail to observe that whilst muscular action hastens the flow of the blood between the point of impulse and the heart

the blood may elude this internal pressure by another and an external course. the circulation would be more obstructed and a cast back in greater quantity on the heart, from the arteries than the veins, if it were true that muscular action has that effect on the motion of the blood which the received theory supposes. Even the view I have just given of the use of the valves, their presence in the arteries is altogether unnecessary. —

I have thus gentlemen endeavoured to set before you what I wish not call a theory of the circulation for your reflections, but a display and arrangement of its phenomena for the test of your future observation and experiment, I would not wish so far to change the duties of pupil and teacher as merely to theorize for you, an employment in which the Master is ever inferior to the Scholar. Nor would I suffering by be guilty of the high crime in science of offering to you my more

it does at the same time retard the flow behind from the point of pressure to the arteries - so that on the whole there could be no gain of velocity and this is conformable to fact, for where mus cular action alone takes place, as in many convulsive diseases, the pulse is never accelerated to the degree that those other causes produce, it is commonly but little excited above standard frequency, and sometimes reduced much below it - The valves therefore are not adapted to any use in a quiescent state of the body and were it never exposed, from shocks, to the kind of motion I have spoken of, they would be altogether superfluous. - According to the doctrine of the valves usually received they would be as necessary to the proper function of the arteries as the veins - for notwithstanding the arteries are more rigid than the veins and capable of resisting greater pressure, still this greater resistance is as nothing to the strong pressure of the muscles which surround them, and since there are no superficial arteries as there are veins, by which

gination on those points that promise an interminable difference of opinion, a crime ~~to which~~ other persons and times will be sure to adjudge the mortifying penalty of Oblivion. — If you wish to accumulate knowledge or fame, keep your unwearied attendance in the school of observation and experiment — ~~But~~ Yet if you must sometimes play the truants of science, go to the subjects of the Brain, of Generation, and animal life, and exercise on them the wantonness fancies of a fabulist. But other points of physiology that like the circulation are palpable and submitted to philosophical enquiry, demand a more manly exertion of intellect. —

James Rush

Philadelphia
Septem^r 1817.